2. SPECIES SELECTION, ESTABLISHMENT AND MAINTENANCE OF GRASS-LINED CHANNELS

By R.M. Ahring and A.G. Davis

The selection of grass species for use in waterways (channels) for erosion control is based on site-specific factors: (1) Soil texture, (2) depth of underlying material, (3) management requirements of vegetation, (4) climate, (5) slope, and (6) type of structure or engineering design. Expected flow rate (Ree and Palmer 1949), availability of seed, ease of stand establishment (germination and seedling growth habit), species or vegetative growth habit, plant cover (aerial parts, height, and mulch), and persistence of established species are other factors that must be considered in selecting the appropriate grass to meet conditions critical to channel stability.

Soil and climate of a particular area determine the best adapted grass species for erosion control in lined channels. The soils of an area in part determine the vegetal association in that:

1) Sandy soils take water rapidly, but do not retain moisture as long as finer textured soils.
2) Moisture is more readily caught, stored, and returned to plants grown on sandy soils.
3) Fine-textured soils are more slowly permeable than sandy soils and are characterized by (a) greater runoff, yet are less erodible; (b) less total storage capacity because of well-developed B horizons; and (c) lower yield of water to plants due to the higher colloidal fraction.

Channel construction should be sequenced to allow establishment of the grass stand before subjecting the channel to flow other than local runoff. This is often possible when the grass-lined channel(s) is built in conjunction with hydraulic structures such as reservoirs or terraces. Completed structures need a quick and uniform cover of vegetation for soil stabilization and erosion control. Establishing permanent covers must be tailored for each location because channel stability is a site-specific problem until vegetation is well established. Establishment involves liming and fertilizing, seed bed preparation, appropriate planting dates, seeding rates, mulching, and plant-soil relationships. These activities must be properly planned, with strict attention to rainfall patterns. Often the channel is completed too late to establish permanent grasses that grow best during the optimum planting and establishment season.

SELECTING PLANT MATERIALS FOR ESTABLISHING TEMPORARY CHANNEL COVERS

Channels are often exposed from a few weeks to 9 months (Ree, 1949) to wind and water erosion unless protected by a temporary ground cover. Based on flow tests on sandy clay channels, Ree et al. (1977) suggested the use of wheat (Triticum aestivum L.) for winter and sudangrass [Sorghum sudanensis (Piper) Hitchc.] for late-summer temporary covers. These temporary covers increased the permissible discharge rate to five times that of an unprotected spillway. Other annual and short-lived perennials used for temporary seedings include (1) barley (Hordeum vulgare L.), noted for its early fall growth; (2) oats (Avena) sativa L.), in areas of mild winters; (3) mixtures of wheat, oats, barley, and rye (Secale cereale L.); (4) field bromegrass (Bromus spp.); and (5) ryegrasses (Lolium spp.). Summer annuals, for example, German and foxtail millets (Setaria spp.), pearl millet [Pennisetum americanurn (L.) Leeke], and certain cultivated sorghums other than sudangrass (Atkins 1957; Vallentine 1971), may also be useful for temporary mid- to late-summer covers. Since millets do not continue to grow as aggressively as sorghums after mowing, they may leave a more desirable, uniformly thin mulch for the permanent seeding. Temporary seedings involve minimal cultural treatment, short-lived but quick germinating species, and little or no maintenance. The summer covers should be close-drilled stands and not be allowed to seed. The protective cover should provide stalks, roots, and litter into which grass seeds can be drilled the following spring or fall.

SELECTING PLANT MATERIALS FOR ESTABLISHING PERMANENT COVERS

Many grasses can be used for vegetal channel linings (Allred and Nixon 1955; Atkins and Smith 1967; Hafenrichter et al. 1949, 1968; Schwendiman and Hawk 1978). The most preferred warm- and cool-season grasses for waterway channels are the tight-sod-forming grasses; that is, bermudagrass [Cynodon dactylon var dactylon (L.) Pers.], bahiagrass (Paspalum notatum Fluggle), buffalograss [Buchloe dactyloides (Nutt.) Engelm.], intermediate wheatgrass [Agropyron intermedium (Host) Beauv.], Kentucky bluegrass (Poa ratensis L.), reed canarygrass (Phalaris arundinacea L.), smooth bromegrass, (Bromus inermis Leyss.), vine mesquitegrass (Panicum obtusum H.B.K.), and Western wheatgrass (Agropyron Smithii Rydb.). These grasses are among the most widely used species and grow well on a variety of soils.

To understand the relation between different grasses and grass mixtures to grass-lined channel use value, one must consider growth characteristics and grass-climate compatibilities in the different geographic areas of the United States. A grass mixture should include species adapted to the full range of soil moisture conditions on the channel side slopes. Table 2.1 is intended primarily to show some of the different kinds of grasses used in grass-lined channels. Conservationists and agronomists of each State should know the best soil-binding grass species adapted to their particular areas, seeding rates, dates of seeding particular grass species, and cultural requirements for early maximum cover. The most important characteristic of the grass(es) selected is its ability to survive and thrive in the channel.

The list of grasses and characteristic growth habits is not complete, and many more species could be added. It is important, however, to know the origin, range of adaptation, and growth habits of the grass strains in conservation work. Grass breeding and selection have resulted in the release of several varieties of a particular grass species. Some varieties may be better adapted to specific areas and site situations, thus requiring less time to become established than others. Bermudagrass is probably the most widely used in the South. It will grow on many soil types, but at times it may demand extra management. It forms a dense sod that persists if managed properly.

When bermudagrass is used, winter-hardy cultivars should be obtained. Improved cultivars, such as 'Coastal' (Burton 1948), 'Midland' (Harlan et al. 1954), 'Greenfield' (Elder 1955), 'Tifton' (Burton and Monson 1978), and 'Hardie' (Taliaferro and Richardson 1980), do not produce seed, and must be established. -by sprigging. Where winters are mild, channels can be established quickly with seed of 'Arizona Common.' Seed of

bermudagrass, a new seed-propagated variety with greater winterhardiness than 'Arizona Common,' was jointly released in 1982 by the USDA-ARS and the Oklahoma Agricultural Experiment Station (Ahring et al. 1982) and should be available commercially within a few years. Bermudagrass is not shade tolerant and should not be used in mixtures containing tall grasses. However, the inclusion of winter annual legumes such as hairy vetch (Vicia villosa Roth.), narrowleaf vetch [V. sativa L. subspecies nigra (L.) Ehrh.] (Ball 1968), and/or a summer annual such as Korean lespedeza (Lespedeza stipulacea Maxim.) may be beneficial to stand maintenance.

The selection of species used in channel establishment often depends on availability of seed or plant material. Chronic national seed shortages of some warm-season grasses, especially seed of native species, have often led to planting seed marginally suited to site situations. Lack of available seed of desired grass species and cultivars adapted to specific problem sites is a major constraint often delaying or frustrating seeding programs. In addition to the grass species or base mixture of grasses used for erosion control, carefully selected special-use plants may be added for a specific purpose or situation. Desirable wildlife food plants may be included in the mixture if they do not compete to the detriment of the base grass(es) used for erosion control. Locally adapted legumes are often added if they are compatible with the grass(es) and noncompetitive.

On large watershed projects, the problems of seed supply should be resolved before a project is started. Special "seed" increase funds may be needed to avoid bottlenecks later in the program. Such funds could be used to contract the production of needed quantities of specific grass seeds over a projected period of time.

GRASS ESTABLISHMENT

Removing topsoil from channel sites before excavating and returning it to the excavated channel is frequently the determining factor in establishing a good uniform grass cover. Usually, it is necessary to save and replace topsoil over the exposed channels. For some channels, however, the subsoil of channel beds, when fertilized, could be an adequate medium for establishing grass. We have no fast rule for determining the depth of topsoil to place over exposed channels other than that topsoil and depth of suitable subsoil should be at least 18 inches for good plant growth and root concentration of seeded grasses. At least 6 to 10 inches of topsoil must be added to establish grass in channels cut in coarse-textured/low-fertility soils. Channel fertilization needs should be based on soil test results, and when needed, fertilizer should be applied at the time of planting, after the topsoil is replaced.

Where channels are excavated into clay subsoils, 12 inches or more of good topsoil should be added back and worked into the top 6 inches of the channel bed and side slopes. Topsoil replacement should be staked for proper depth to make use of available soil quantities. Tillage measures should be taken to limit slippage at contact layers and to promote plant root penetration and water infiltration. Grass species that have high tolerance for soluble salts and exchangeable sodium should be established on channels cut in highly saline and alkali soils.

To expedite control of erosion and sediment, seedings must be made almost concurrently with channel excavation. When moisture conditions are not favorable and irrigation is practical, short supplemental irrigations may be used to hasten the growth of a suitable cover. Permanent seeding should be timed to obtain the maximum establishment before exposure to flows.

The technology, equipment, and plant species used in other areas, for example, roadside stabilization (Environmental Protection Agency 1975) and land rehabilitation (Cook et al. 1974; McKell et al. 1979; Robbins 1980; Schuman and Power 1980), are applicable to the stabilization of grass-lined open channels.

Preplanting Considerations

Before planting, a soil test should be made to test soil pH and insure that nutrients, especially nitrogen, phosphorus, and potassium levels, are adequate.

A firm, weed-free seedbed, with just enough loose surface soil for uniform depth of cover, is essential. Such a seedbed is important in obtaining uniform planting depths and improving seed-soil contact. Seed planted in loose soil is usually planted too deep, and seedlings fail to emerge; or seeds may

germinate following a light rain but die after the soil dries out before seedlings can develop sufficient roots for establishment.

Soil temperature (65 to 86°F for warm-season grasses and 60 to 86°F for cool-season grasses) and moisture must be favorable. Time of seeding should be based on whether species are classified as cool- (fall-sown) or warm-season (spring-sown) grasses.

Planting dates should be selected to avoid expected periods of critical weather, such as heavy rainfall and runoff, and extended dry periods.

Select adapted species or a combination of adapted grass species which will withstand the degree of inundation expected, establish themselves rapidly from seeds or sprigs, and compete well with weeds. Also, consider the possible use of certain preemergence herbicides to control weeds during establishment (Huffine et al. 1982; Kay 1971; McMurphy 1969; Smith 1983).

Where severe weed problems are anticipated, spraying activated carbon (20 to 27 lb/acre) slurries (Lee 1973, 1978; Rolston et al. 1979) in narrow bands on the soil surface of each seed row at the time of planting, followed by a broadcast application of nonselective herbicide(s), may be a useful technique. The activated carbon absorbs and inactivates the herbicide, giving a narrow band of protection above the seed zone.

Seed Germination

Uniform seed germination is essential to producing a uniform cover over the entire site. Germination can be enhanced by consistency and attention to contributing factors.

Seed should not be planted deeper than 0.25 inch (heavy soils) to 0.75 inch (light soils). Small discrepancies in depth of planting in heavy soils can be disastrous. Special grass drills with depth band openers are available to get proper planting depths.

Planting dates should be timed to favorable moisture and soil temperatures conducive to germination and seedling establishment.

A seeding rate should be selected to give the desired number of plants per unit area. Uniformity of established cover is essential to prevent flow and boundary stress concentration within the channel. Mixtures require a higher seeding rate than does a planting of a single species. The SCS specifications for

critical area seedings recommend one and one-half to two times the normal seeding rate. However, where a vegetative cover is urgently needed, seeding rates of mixtures probably should include enough seed to obtain a stand of each species alone in the event conditions are not favorable for germination and emergence of one or another species in the mix. Although mixtures may be more effective on certain sites in reducing erosion and resisting weed encroachment, mixed plantings should be kept simple (Decker et al. 1978; Huffine et al. 1982). No more than two or three species in a mixed planting is preferred. The mixture seeded should be solely for erosion control. Dual-purpose seedings tend to weaken the required surface protection and cause conflicts in maintenance.

Where temporary channel covers are established the year before and mowed before seed is formed, it may be necessary to cultipack the area before planting in the spring. During late fall or early spring, cool- and/or warm-season grasses can be drilled into the undisturbed mulched firm seedbed.

Where winter annuals have been used to stabilize channels, herbicides can be used to kill the stand early before growth is too heavy. The herbicide application should also eliminate winter weeds. Direct seed the warm-season grass(es) without removing any of the mulch litter. The seedbed beneath the mulch should be firm. Whenever planting is done on littered or mulched seedbed, use special grass drills with double coulter openers to cut through the mulch.

Stand Failure

Stand failures can be attributed to any one, or combination, of several factors. Seedling growth after emergence may be affected by undesirable soil pH, low soil fertility, improper use of preemergence and postemergence herbicides, or soil compaction by heavy machinery. Other causes of stand failure are-

1) Use of seed that has a high percentage of firm (dormant) seeds can result in slow germination, permitting the weed seeds to germinate and emerge well ahead of the intended grasses.

2) Lack of chemical or mechanical weed control can cause poor seedling establishment, since weeds compete with grass seedlings for soil moisture, nutrients, and light.

3) Failure to protect a channel from concentrated runoff following a storm, or crusted soil surfaces resulting from heavy rains after planting, can prevent emergence of grass seedlings, especially on fine-textured soils.

4) High wind velocities and movement of sand particles can be a hazard to stand establishment, especially on coarse-textured soils.

5) Winter-kill because of late planting in the fall, late emergence of an earlier planting, or planting nonadapted grass cultivars can result in stand failures.

6) High temperatures on soil surfaces and drought probably are the most common causes of stand failure.

The critical need for grass-lined channel structures is a vegetative cover of uniform density and height (McCool 1970; Temple 1982) at the time of flow. Success in stabilizing water channels requires a great deal of skill. In some channels, a quick establishment of cover is required. In others (notably spillways and floodways), proper planning can allow adequate time for establishing cover.

Methods of Establishment

Grass seeds are small, often chaffy, and difficult to plant without special equipment. Several planting methods follow.

The drilling method of planting seed using a depth band grass drill is recommended in channels where seedbed preparations are smooth. Drills utilize the available seed more efficiently, place the seed more accurately, and increase the probability of establishment success. In drill planting, rows paralleling the channel flow should be avoided, and close row spacings should be used to maximize uniformity of cover. Rough seedbeds hold more water and reduce the chances of wind damage better than smooth seedbeds. However, rough, cloddy seedbeds require a higher seeding rate because planting depths (soil covering) and soil-seed contact are not uniform. Usually only a small fraction of the viable seed planted on such seedbeds produce surviving seedlings. A wide selection of grass seed drills are available (Larson 1980). Most feature double or single-disk furrow openers, with and without depth-band gauges attached'to the disks, and heavy-duty press wheels or drag devices to cover the seed. Hoppers are similar to conventional drills with the addition of various agitators and feed mechanisms for planting chaffy seed.

The broadcast method involves spreading seed over the area intended for establishment followed by a cultipacker or drags to ensure the seeds are covered with a uniform layer of firm soil. Types of broadcast planters used vary from tractor-mounted rotary spreaders to Brillion® seeders. As a rule, broadcast planting requires about twice as much seed to obtain a uniform stand as does drilling.

Sprigging, sodding, and mulch sodding are common methods of establishing bermudagrass. The minimal rate for establishing channels to bermudagrass is 40 bu/acre equivalent of viable sprigs (rhizomes and stoloniferous plant material). Sprigging rates required vary with quality of sprigs and time of year. Planting equipment (sprigger) should be operated at about 4 mph and adjusted to plant sprigs uniformly at 3 to 4 inches deep in 18- to 24-inch rows. After planting, the channel should be compacted and watered.

In sodding, a well-developed sod (source) is cut 10 to 12 inches wide and 3 inches thick and laid tightly in rows at right angles to the slope. Sod-slab joints are staggered from one row to the next. All openings in the laid sod and joints are filled with friable soil, and the area is rolled or tamped for firm sod-soil contact. A tiedown wire (poultry wire) is often used to hold sod in place and prevent erosion until roots tie soil layers together. Structures sodded are usually watered to stimulate sod recovery.

For mulch sodding, the sod source is thoroughly cut up and mixed to a 4- to 8-inch depth by disking in two directions. This 4 to 8 inches of topsoil and chopped sod material (mulched sod) is then removed and dumped on the roughly tilled (4-inch depth) site and spread to a thickness of at least 4 inches. Following compaction, the mulch channel should be watered (3 to 4 gal/yd^2).

Hydroseeding and mulching provide a method of planting on moderate to steep slopes, but require large amounts of water (Huffine et al. 1982; Young, et al. 1977). Hydroseeding should be followed by mulching as a separate operation. Mulches include:

1) Long-stem wheat straw (preferred), clean prairie hay, and so forth. Straw or hay mulches are either broadcast and "punched" in (4-5 inches deep) on moderate slopes with a straight disk, or broadcast along with an adhesive or tacking agent (that is, asphalt emulsion) on steep slopes. About 1.0 to 1.5 tons/acre of straw is ideal. Mulches conserve surface moisture and reduce summer soil surface temperatures and crusting. The disadvantages of hay and straw mulches are that they can be a source of weed seed, and too much surface mulch, regardless of kind, can cause seedling disease problems, for example, "damping-off." Commercial wood fiber mulch materials are available for relatively level areas.

2) Soil retention blankets or mats made of various interlocking fabrics and plastic webbing can be used on extremely steep slopes in areas with a high potential for water movement. These tiedown erosion blankets prevent seeds from being washed out by rain, and at the same time mulch and enhance germination and establishment.

New methods of establishing grasses that may have future merit for grass-lined channels are the "fluid" drill and the "Automatic Bandoleer" seedling transplant methods.

The fluid drill method involves planting partially germinated seedlings (root-radicle exposed) suspended in carrier "gels" (starch base). By means of peristaltic pumps, the gel containing partially germinated seeds is extruded into the seedbed immediately behind coulters. The drills will sow controlled beads of gel with a consistent number of partially germinated or primed seeds per length of row.

With the Automatic Bandoleer transplanting method (Hauser 1981), plants are grown from seed under greenhouse conditions in bandoleers, or growing trays, for machine planting. The transplant machine pushes plugs with growing seedlings into furrows and firms the soil around the plant.

Advantages of both methods are (1) uniform planting density, (2) a rapid and predictable emergence of seedling and transplant survivability, (3) reduced susceptibility to environmental stresses and uncertainty of obtaining suitable stands from seed, and (4) reduction of poor seedbed quality or preparation as a detriment to stand establishment. The disadvantage is the initial cost of the methods.

MAINTENANCE OF VEGETATION

Manmade grass-lined channels encompass diverse soil types, climate-vegetal associations, and topography. Management plans with stated goals and objectives are necessary to maintain and direct water flow drainage and prevent damage to channel structures. Grass-lined channels should be inspected after heavy rains and in the spring after the snow melts so that potential problem sites can be detected and repaired. Inspections should be made at regular intervals on foot. Ifvehicles must be used, the route taken should never be used twice in the same season because of track damage and the danger of track erosion,

Undesirable weedy plants often invade channels, especially on channel side slopes, and create problems of water flow (Gwinn and Ree 1980) by impeding or redirecting water movement. If allowed to persist and spread, these undesirable plants can cause severe erosion damage to the channel.

Weeds

Three categories of weeds are (1) grasses, (2) broadleaf, and (3) woody. The first step in weed control and management is to find the cause of the weed infestation. Weed control (killing) without correcting the basic cause of the problem will give only temporary relief, will not regenerate the established stand, and will increase costs of channel maintenance over time. Weed control may result in substantial discontinuities in density of cover and cause boundary stress concentrations that lead to an unravelling of the channel through gullying and undercutting of the vegetal cover. Burrowing rodents also can cause similar problems. Use of nitrogen fertilizers may stimulate the self-healing capability of some of these covers.

Causes of weed infestation include:

1) Failure to control weeds in early stages of infestation.

2) Establishment of grass species not well adapted to either climate and/or soil conditions of a particular area.

3) Poor soil fertility--some grasses may become sod-bound (nitrogen deficient) or unproductive due to plant nutrient deficiencies other than nitrogen.

4) Competitive nature of weeds--severe winter and dry spring weather may delay spring emergence and growth of desired perennial grasses, thus allowing weeds a competitive edge over winter annuals.

5) Thatch buildup or shading--such conditions can contribute to stand thinning, thus allowing encroachment of weedy plants.

6) Mowing--height, timing, and type of mowing can weaken stand persistence and increase susceptibility to weed encroachment.

7) Soil.- and root-infesting insects--white grubs, the young immature larvae of the brown May (and June) beetles, and nematodes, for example, often infest grass sod, feeding on roots. Heavy infestations can severely weaken stands of desirable vegetation.

Channel Vegetal Composition and Control Management Practices

Where existing plant species composition is not desirable, efforts should be made to introduce more desirable species. Depending on management objectives, interseeding, fertilization, herbicides, hand grubbing, mowing, and/or haying can be used independently or in combination to change vegetal composition (Herbel 1983).

Interseeding

The introduction of new species into existing stands of vegetation requires that (1) the introduced species is highly competitive, (2) the area to be interseeded is cleared of existing plant residue either by burning or by mechanical or chemical removal, (3) contact and preemergence herbicides (Martin et al. 1982; McMurphy 1969; Robinson and Greene 1976; Samson and Moser 1982) are used to surpress existing competition and prevent a weed infestation, and (4) proper planting rates and dates of planting are used.

Because of channel erosion potential, interseeding should be done with minimal disturbance of the soil. The success of interseeding depends on the kind of treatments done before or during planting to remove competition from existing vegetation.

Fertilization

Channel vegetal composition may be changed simply by timed and controlled application of fertilizers: lime, nitrogen alone, or a combination of nitrogen (N) plus potassium (K), phosphorus (P), or lime. Soil tests determine the amount of nutrients applied to a particular site through fertilization. Over most of the West, soil K and calcium (Ca) levels are usually adequate for good grass growth. Much of the Midwest, Northeast, Southeast, and the Northern Pacific Coast, however, generally require both lime and K in addition to N and P.

Soil fertility requirements, especially for P, K, and Ca, should be met before establishing the grass lining for a channel. The more mobile N can be added as needed in spring, fall, or split spring/fall applications. The best time to apply fertilizer is determined by the kind of grass, the amount and distribution of rainfall, and the kind of fertilizer being applied. Nitrogen

fertilizer, when other essential nutrients are adequate, is the most important grass maintenance practice. Single spring and split spring/fall applications of N are beneficial on a number of warm-season, as well as cool-season, grasses. Although summer applications of N may be beneficial on certain warm-season grasses, for example, bermudagrass, they may be damaging to cool-season grasses. Cool-season grasses are usually fertilized in the fall and again in early spring for maximum growth. Excessive once yearly N-application rates should not be used for grass-lined channels. Rates between 30 and 60 lb of N per acre applied in early spring and again in the fall should maintain most warm- and cool-season grasses in excellent condition. Fertilization can be a long-time cure, a preventive measure, and/or a temporary solution.

Selective Herbicides

The success in controlling undesirable plants with herbicides depends on the correct identification of the target plant(s) and the use of the right herbicide applied at the right time. It is unlawful for any person to use any registered pesticide in a manner inconsistent with its label. The USDA "Compilation of Registered Uses of Herbicides" (Carter 1980) lists a number of selective herbicides for use on roadsides, highway rights-of-way, drainage ditches, pasture, rangeland, and turf (lawns). Some herbicides are approved in certain States for preemergence use in the establishment of certain grasses. A selective sampling of the extensive literature (Kay 1971; Martin et al. 1982; McMurphy 1969; Moomaw and Martin 1978; Robinson and Greene 1976; Samson and Moser 1982; Smith 1983) on the use of selective herbicides in the establishment of grasses is sufficient to show that considerable attention is being given the subject. Grass seedlings are, however, rate sensitive, and labeled application rates of approved use chemicals should not be exceeded.

The use of selective herbicides and fertilizers to shift vegetal composition, for example, removing undesirable grass competition, is a well-established science. Herbicide applications in grass-lined water channels may be questioned, however, for fear of stream and reservoir pollution.

Mowing

Mowing properly timed may aid in the control (especially during establishment) of certain weedy annual grasses and broadleaf weeds while preventing seed formation of undesirable species. Occasionally grass-lined channels may need to be mowed to maintain flow capacity. The frequency of mowing depends on the reason for mowing--whether to cause vegetation changes in the channel, control weeds, improve cover uniformity, or increase channel capacity. Other hydrologic and hydraulic factors related to channel use may also need to be considered in determining the timing and frequency of mowing and other maintenance

practices. Removing vegetative growth as hay at times helps prevent undesirable thatch accumulation.

Frequent mowing to eliminate invading taller growing species (forbs and grasses) leads to a stand cover of lower growing sod grasses, such as bermudagrass and buffalograss. Mowing to reduce undesirable plant competition is a means of maintaining a desired composition of channel grasses.

Burning

Burning can be an excellent management tool to remove thatch, but it is potentially dangerous not only to vegetation ground cover of the burned site but also to those doing the burning and the public unless prescribed procedures are followed (Wright and Bailey 1980). Burning must be supervised and should conform with the requirements of any local fire authority.

If burning is used, plan to burn at a proper time. Use moist mulch; wind should be sufficient (5 mi/hr, but less than 10 mi/hr) to carry the fire rapidly; and manpower and equipment should be available to control the fire. Weather conditions (45 to 60 percent relative humidity, wind less than 10 mi/hr, air temperature of 40 to 60°F) during burn are extremely important. Timed properly with soil moisture and moist mulch present, burning is not injurious to most warm-season grasses. Burning should be done in the early spring about the time regrowth begins. Mulch of old vegetation must be dry enough to burn, but moist enough to reduce plant crown injury. If channels are burned too early in the spring, considerable time may elapse before vegetative regrowth. Thus, with soil exposed, runoff following heavy early-spring rains may damage the channel. Grass-lined channels established to cool-season grasses can be severely damaged by spring burns. Burning of these grasses, if necessary, should be done only in late summer or early fall.

Burning aids in weed, insect, and disease control. Not only does it allow complete thatch removal, it increases the effectiveness of fertilizer and herbicide applications and results in more uniform spring (warm-season) and fall (cool-season) growth. In certain situations it is an efficient way to decrease undesirable vegetation and promote desirable species.

ADDITIONAL CONSIDERATIONS

The design engineer must consider design risks when relying on as the stabilizing medium. The designer should--

1) Plan the channel to make maximum use of existing acceptable vegetation.

2) Use side slopes of 2:l or flatter to enhance seeding and establishment of vegetation.

3) Require berms and spoil areas to be graded to minimize or eliminate flow of surface water over channel side slopes.

4) Plan inlet structures, riprapped curves, culvert outlet protection, and so on, to minimize disruption of flows and thus reduce attack on vegetated boundaries.

5) Include construction of 50-100 ft of lateral channels in the prime contract when laterals are scheduled for later construction, so that vegetation on the main channel is not disturbed at the later date.

6) Schedule construction of the channel to coincide with optimum seeding dates.

7) Include seeding specifications in the contract for early seeding and optimum moisture conditions in side slopes.

8) Consider use of diversions, temporary plugs with small culverts, or other means to limit velocity in the channel until a vegetative cover is established.

Conditions that may prevent the use of grass as an effective lining for channel stabilization are (unpublished, USDA ENG.-Committee 2-5 draft of Proposal No. 4 Vegetation as a Channel Stabilizer, 1971):

1) The climate will not support a sufficient cover of herbaceous vegetation to provide year-round protection.

2) The soils in the channel side slope are highly erodible and not capable of supporting permanent vegetation.

3) Channel base flows prevent the use of grass vegetation as a stabilizer for the channel bed.

4) Channel designs are not sufficient to handle design flows, thus increasing the risk of scouring.

Table 2.1
Characteristics of selected grass species for use in channels and waterways

Grass species	Growth habit		Roots		Adaptation				Establishment				Height at maturity ft
					Site		Soil		Seed		Rhizome or stolons		
	Bunch	Sod	Fibrous	Rhizomes-stolons	Lowland	Upland	Sandy	Silt-clay	Fast	Slow	Fast	Slow	
Cool-Season Grasses													
Creeping foxtail *Alopecurus arundinaceus* Poir.		+		+	+			+		+			3-4
Crested wheatgrass *Agropyron desertorum* (Fisch. ex Link) Schult.	+		+			+		+		+			2-3
Green needlegrass *Stipa viridula* Trin.	+		+			+		+		+			3-4
Russian wildrye[1] *Psathyrostachys junceus* (Fisch.) Nevski	+		+			+		+		+		+	3-4
Smooth bromegrass[2] *Bromus inermis* Leyss.		+		+		+		+	+				3-4
Tall fescue *Festuca arundinacea* Schreb.	+		+		+	+		+	+				3-4
Tall wheatgrass[1] *Elytriga pontica* (Podp.) Holub	+		+			+		+		+			4-5
Western wheatgrass[1] *Agropyron smithii* Rydb.		+		+	+	+		+		+	+		2-3
Warm-Season Grasses													
Bermudagrass *Cynodon dactylon* (L.) Pers.		+		+	+	+	+	+	+		+		3/4-2
Big bluestem *Andropogon gerardii* Vitm.		+		+	+	+		+		+		+	4-6
Blue grama *Bouteloua gracilis* (H.B.K.) Lag. ex Steud.		+	+			+		+		+			1-2
Buffalograss *Buchloe dactyloides* (Nutt.) Engelm.		+		+		+		+	+		+		1/3-1

Green sprangletop *Leptochloa dubia* (H.B.K.) Nees	+		+				+	+	+	+			3-4
Indiangrass *Sorghastrum nutans* (L.) Nash		+		+	+		+	+	+	+		+	5-6
Kleingrass *Panicum coloratum* L.	+		+				+		+		+		3-4
Little bluestem *Schizachyrium scoparium* (Michx.) Nash		+					+	+	+	+		+	3-4
Plains bristlegrass *Setaria macrostachya* H.B.K.	+		+				+	+	+		+		1-2
Sand bluestem *Andropogon hallii* Hack.		+		+	+		+	+			+	+	5-6
Sideoats grama *Bouteloua curtipendula* (Michx.) Torr.	+			+			+	+	+	+		+	2-3
Switchgrass[3] *Panicum virgatum* L.		+		+	+		+	+	+	+		+	4-5
Vine mesquitegrass *Panicum obtusum* H.B.K.		+		+			+		+		+	+	1-2
Weeping lovegrass *Eragrostis curvula* (Schad.) Nees	+		+				+	+		+			3-4
Old World Bluestems[4]													
Caucasian bluestem *Bothriochloa caucasica* (Trin.) C.E. Hubb.	+		+		+		+	+	+	+			4-5
'Ganada' yellow bluestem *Bothriochloa ischaemun* var. *ischaemun*	+		+		+		+	+	+	+			3-4

Table 2.1--Continued
Characteristics of selected grass species for use in channels and waterways

Grass species	Growth habit		Roots		Adaptation				Establishment				Height at maturity
					Site		Soil		Seed		Rhizome or stolons		
	Bunch	Sod	Fibrous	Rhizomes-stolons	Lowland	Upland	Sandy	Silt-clay	Fast	Slow	Fast	Slow	ft
Old World Bluestems--Con.													
'King Ranch' yellow bluestem *Bothriochloa ischaemun* var. *songarica* (Rupr. ex Fisch. + May.) Celar. + Harlan	+		+			+		+	+				3-4
'Plains' yellow bluestem *Bothriochloa ischaemun* var. *ischaemun*	+		+		+	+		+	+				3-4
'WW-Sparr' yellow bluestem *Bothriochloa ischaemun* var. *ischaemun*	+		+		+	+	+	+	+				3-4

[1] Alkali tolerance good.
[2] Two types: Northern and Southern.
[3] Two types: upland, for example, 'Blackwell', and lowland, 'Kanlow'.
[4] Wide differences within species; select strains that are adapted and meet planting objectives.

NEXT PREVIOUS CONTENTS